NOx.

NOx concentrations in Pool 2 (RM 847.5 to RM 815) have shown a notable increase over the 20-year monitoring period. The requirement for ammonia nitrogen removal (conversion of ammonia to nitrate via a nitrification process) at Twin Cities Metropolitan Area municipal wastewater treatment plants in the mid-1980s to early 1990s may be an important factor influencing this increase (Sullivan, 2000 and Stark et al. 2000). The Minnesota River is also a substantial contributor of nitrate nitrogen to Pool 2, with increased loads in the 1990s compared to the 1980s (Scott Schellhaass, MCES, St. Paul, MN). In general, river-wide NOx data also indicated higher concentrations in the 1990s than in the 1985-1989 time period, with the increased concentrations likely being flow-related. The drought of 1987-89 resulted in reduced nonpoint source contributions and greater utilization of nitrate (via assimilation and denitrification) during periods of low summer flow. The return to average and above average summer flows in the 1990s likely favored increased nonpoint source NOx loading, due to increased mobilization of NOx from soil, groundwater and drainage systems (Goolsby et al. 1999).

Total Ammonia Nitrogen

Total ammonia nitrogen (NHx) includes both un-ionized ammonia and ionized (ammonium) forms. The percentage of each form is influenced to a greater extent by pH and to a lesser extent by water temperature and other factors. Decomposition of nitrogen-containing organic material (ammonification) is an important biological process that generates NHx. Major cultural sources contributing NHx to surface waters include municipal wastewater discharges, runoff from feedlots, and other animal waste inputs (Wiener et al., 1984).

Until the 1995-1999 time period, the highest NHx concentrations in the UMR were observed below the Twin Cities Metropolitan Area in Pool 2 (RM 847.5 to RM 815)., These elevated NHx concentrations were especially apparent during the 1980s (Figures 27, 28, and 29). During the 1990s, however, NHx concentrations have decreased dramatically in this river reach, due to reduced NHx loading from municipal wastewater treatment plants through the use of the nitrification process (Kroening and Andrews, 1997 and Sullivan, 2000). This reduced ammonia input quickly diminishes downstream due to rapid nitrification, utilization by aquatic plants, and dilution by the St. Croix River (RM 811.5).

Elevated NHx concentrations (0.5 to 1 mg/L) were also observed at East Dubuque, IL (RM 579.9), Rock Island, IL (RM 481.4), Burlington, IA (RM 404.2) and Hannibal, MO (RM 310.1) during the 1985 to 1989 and 1995 to 1999 periods (Figures 27, and 28). Follow-up discussions with the agency providing this information (Dave Bierl, USCOE, Personal Communication) revealed that there were quality assurance problems with some of these data. This resulted in the decision to remove high NHx values (> 1 mg/L) from the summer data set for the most recent time period (1995-1999). The remaining NHx

Figure 27 - Total Ammonia Nitrogen Concentrations in the Upper Mississippi River

Summer Data Collected over Four Time Periods

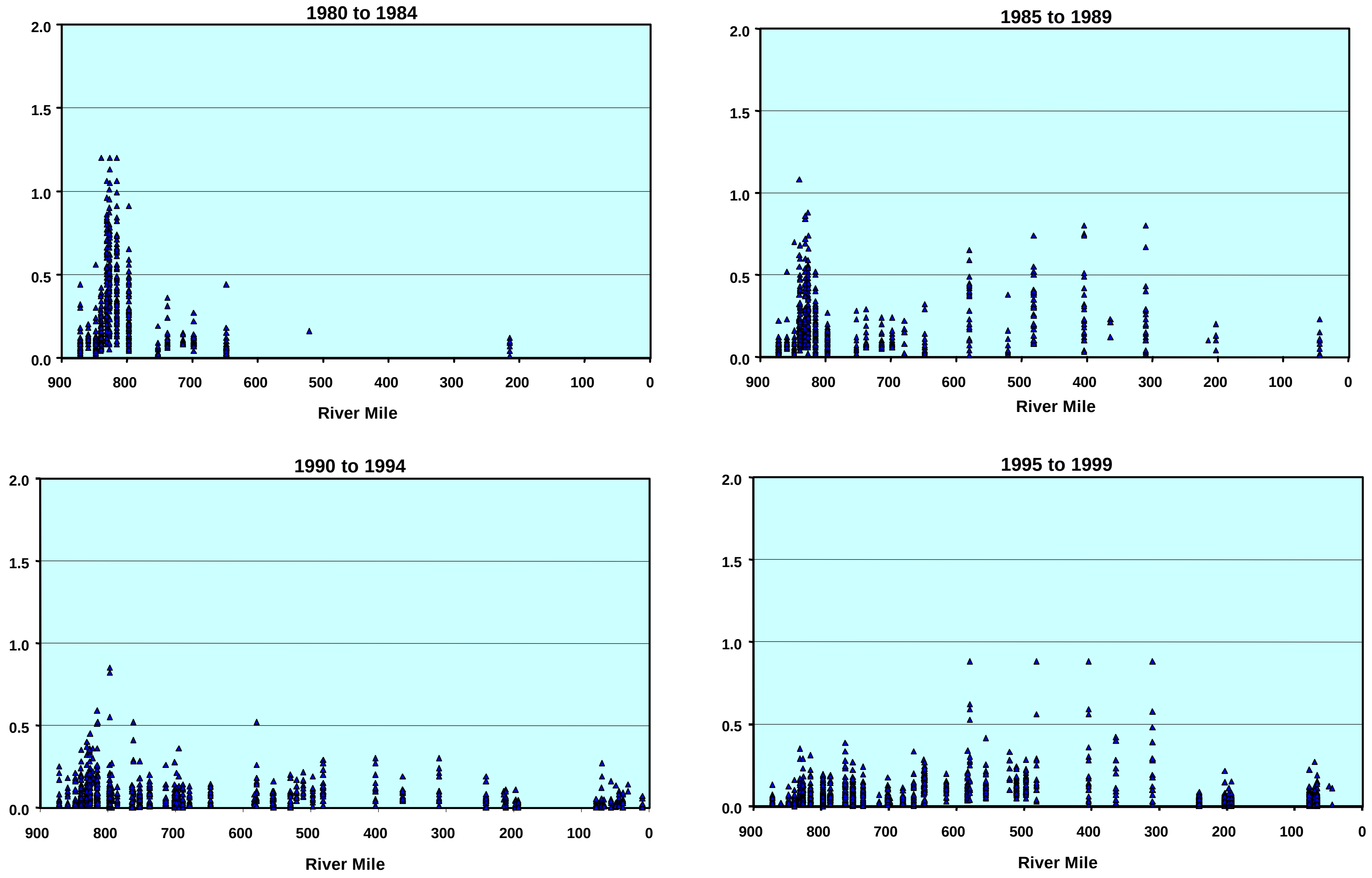


Figure 28: Boxplots of NHx Data by HUC over four time periods

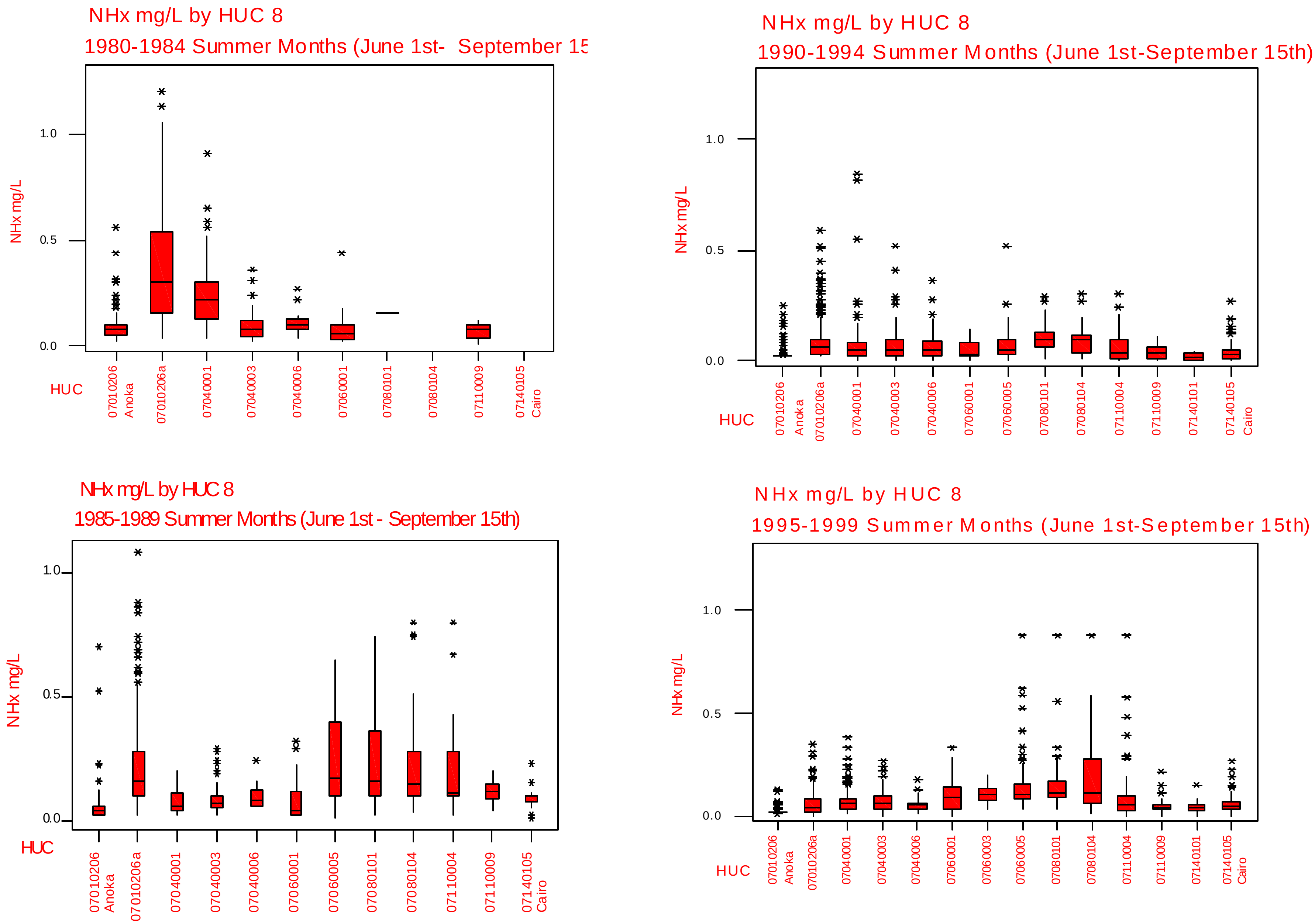
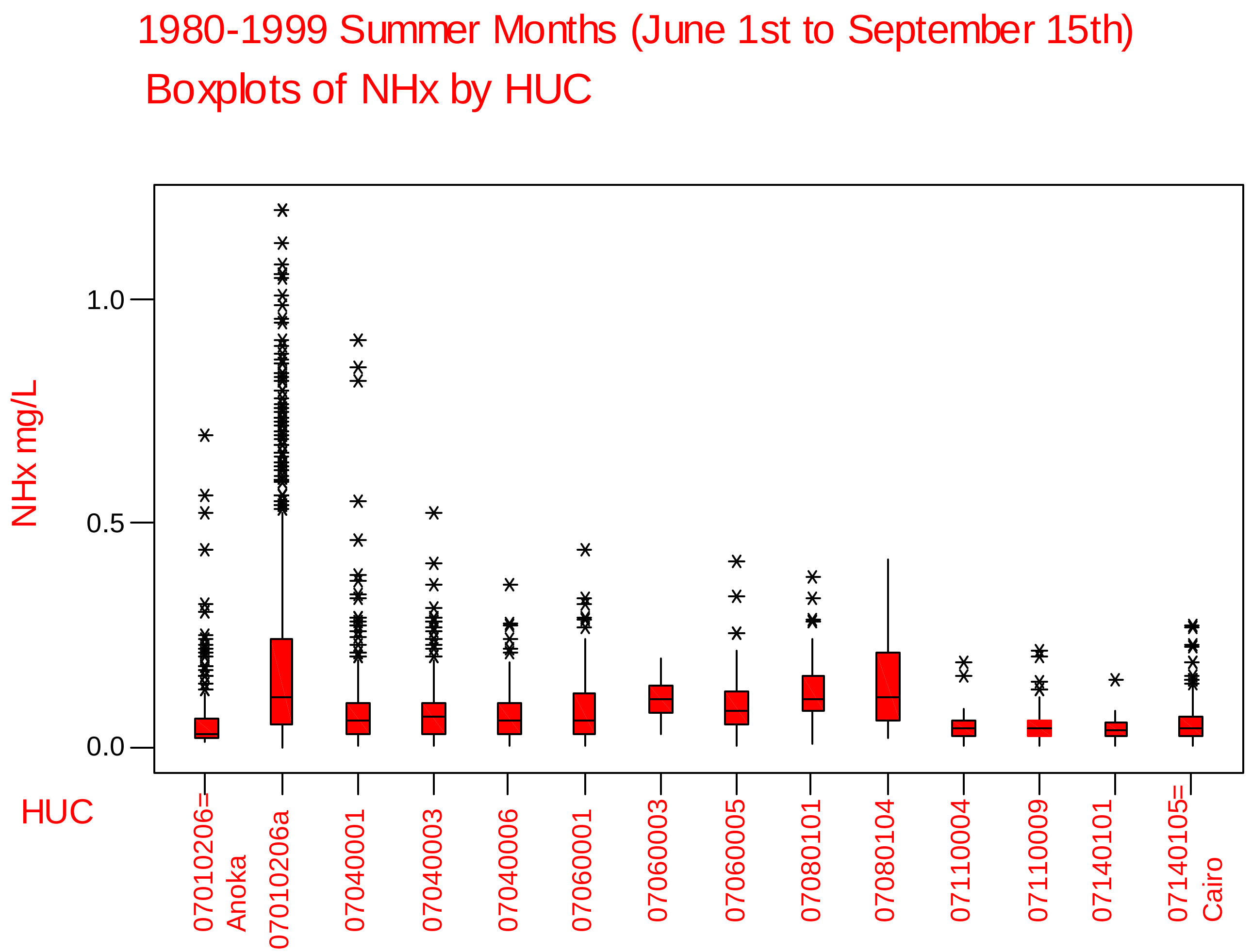


Figure 29: Boxplot of Total Ammonia Data by HUC over 20 years



values reported for these stations are suspect and don't agree with data collected by other agencies in the central portion of the UMR.

Un-ionized Ammonia Nitrogen

Un-ionized ammonia nitrogen (NH_3) is the form of inorganic nitrogen that is toxic to aquatic life. Some states utilize a NH_3 criterion of 0.04 mg/L for the protection of warm water aquatic life. The amount of NH_3 present in water is determined by a calculation using NHx, pH, and temperature. The fraction of NHx present as NH_3 is especially influenced by pH, with NH_3 concentrations increasing as values increase. Measurements of pH were not consistent between or within the agencies supplying the water quality data, with some agencies reporting either field or laboratory pH values, and some agencies occasionally reporting both values. When both field and lab pH values were available, the NH_3 calculation was based on the average of both values. It is possible that there may be some bias in the NH_3 determinations as a result of these factors, however, no further evaluations were conducted to assess this potential problem.

In general, the longitudinal profile of NH_3 concentrations in the UMR reflects that for NHx, except that the concentrations are notably lower (<0.01 to 0.15 mg/L), (Figures 30, 31, and 32). The highest NH_3 concentrations were reported below the Twin Cities Metropolitan Area in the 1980s, prior to ammonia removal at the local wastewater treatment plants. Concentrations of NH_3 have diminished greatly in the upper reach of the river, and were substantially below the 0.04 mg/L criterion during the 1995 to 1999 period. The high NH_3 values observed at a few sites in the central portion of the UMR in the 1985 to 1989 period are suspect, since these are the same sites where the NHx data are questionable (see discussion above on total ammonia nitrogen).

Total Phosphorus

Like nitrogen, phosphorus is an essential plant nutrient and is normally the major element affecting eutrophication in freshwater systems. Also like nitrogen, phosphorus can be measured in several forms, but total phosphorus, representing the sum of all those forms, is most commonly measured and reported in water quality surveys. For the purpose of this report, total phosphorus was selected for assessment, since data were consistently available for the UMR. Although dissolved inorganic phosphorus (DIP), typically reported as soluble ortho-phosphorus or soluble reactive phosphorus, is more directly available for plant uptake and growth, DIP was not commonly measured by all agencies, andwas not considered as a part of this evaluation. The U.S. EPA has previously suggested a total phosphorus concentration of 0.1 mg/L as a general guidance for protection of flowing waters from eutrophication (Mackenthun, 1973). National and

Figure 30 - Un-ionized Ammonia Nitrogen Concentrations in the Upper Mississippi River

Summer Data Collected over Four Time Periods

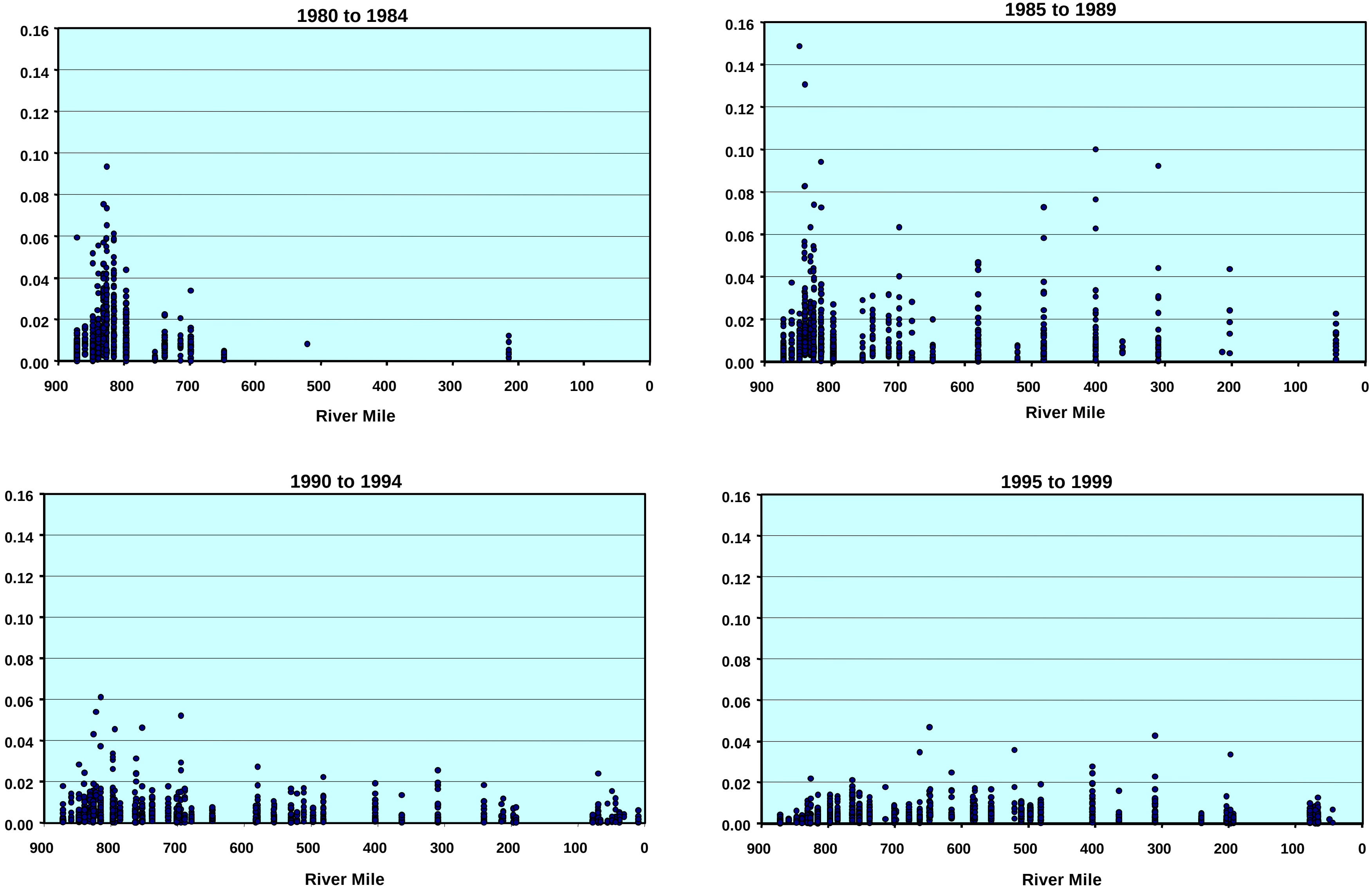


Figure 31: Boxplots of Un-ionized Ammonia Data by HUC over four time periods

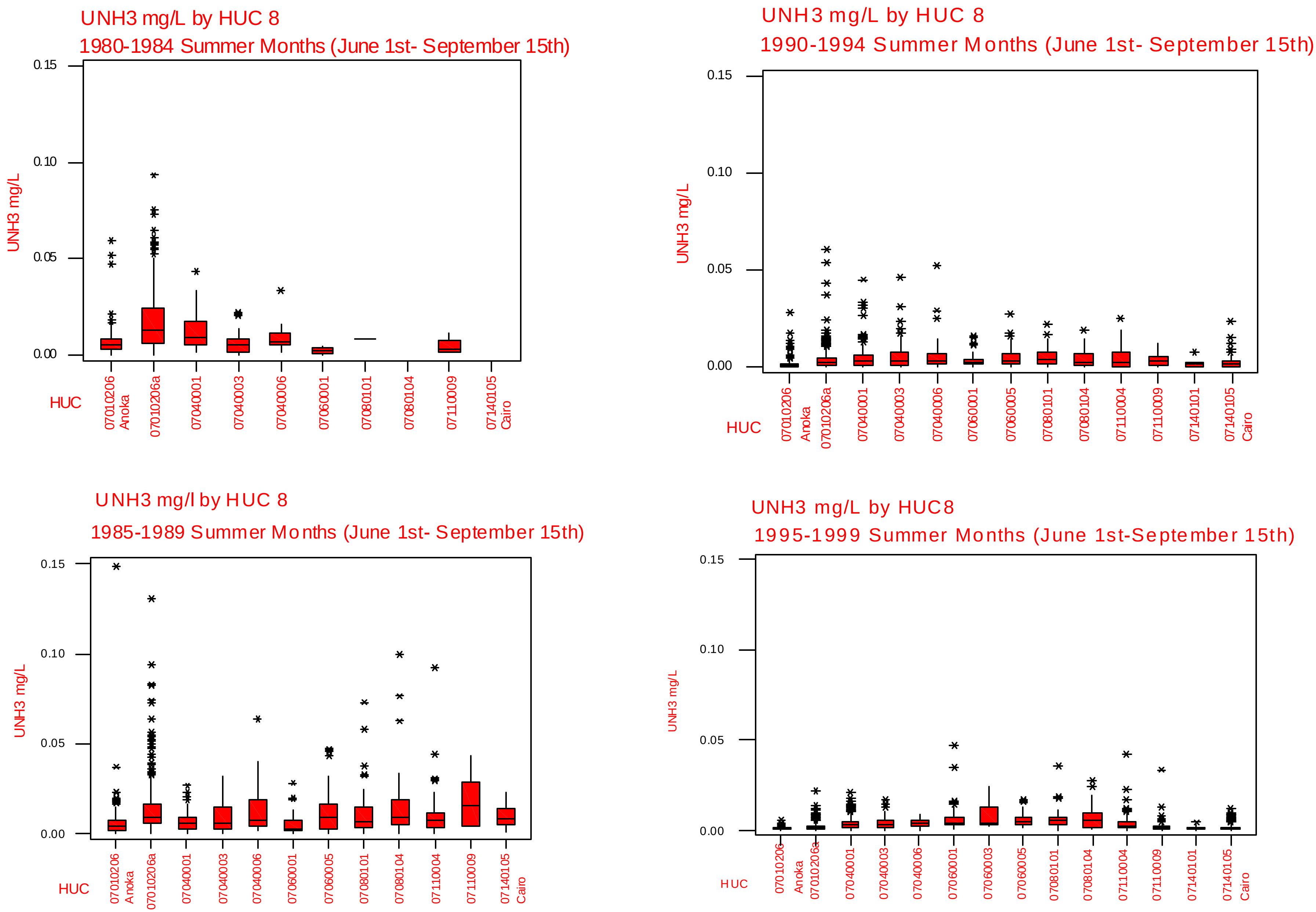
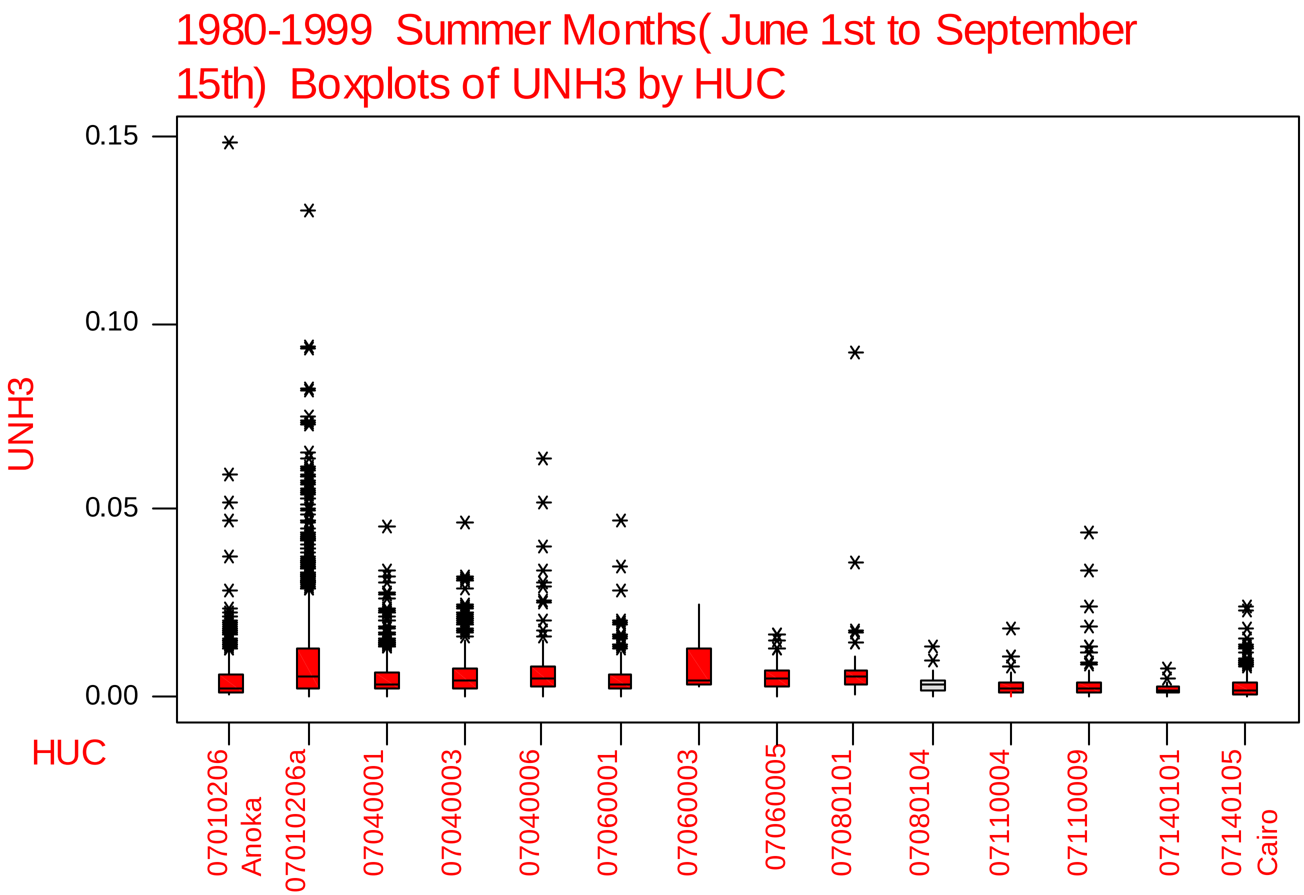


Figure 32: Boxplot of Un-ionized Ammonia Data over 20 years



state efforts are currently underway to develop more formal nutrient criteria for lakes and streams (USEPA, 1998).

Total phosphorus concentrations were very high throughout the entire UMR, with values greater that 0.5 mg/L at many sites (Figure 33). In general, wastewater treatment plant discharges and urban and agricultural nonpoint source inputs are major sources of phosphorus. In particular, agricultural watersheds contributing high concentrations of sediment are especially important, since phosphorus is commonly bound to sediment particles. Maximum phosphorus concentrations exceeded 1 mg/L at many sites during the most recent time period (1995 to 1999) as compared to the previous monitoring periods. Some of these high phosphorus concentrations are likely associated with high total suspended solids concentrations (> 200 mg/L), especially in the lower half of the UMR (Figure 36). This relationship does not appear to explain the high phosphorus values observed in the upper portion of the UMR, where lower suspended solid concentrations were observed. However, the Minnesota River is a major contributor of suspended solids and phosphorus to the upper portion of the UMR. The boxplots did not show any consistent longitudinal patterns in total phosphorus concentrations (Figures 34 and 35).

Total Suspended Solids

Total suspended solids (TSS) represents the amount of filterable particulate material in water, expressed as mg/L. In general, the concentration of TSS increases with increasing river flow. Higher flows may result in increased sediment suspension or may reflect periods of runoff, both of which would contribute to higher TSS concentrations. In particular, runoff from watersheds with a predominance of cultivated lands is an important source of suspended matter in the river. In addition, stream bank erosion in many tributaries can contribute large loading of TSS to the river during high flow events. Once TSS has reached the river, the particulate material may contribute to sedimentation problems in backwaters, negatively influence submersed aquatic plant growth due to decreased light penetration, smother benthic invertebrates, and lead to other impairments. The states have not adopted TSS standards for the river.

Highest TSS concentrations (> 500 mg/L) in the UMR are found in the lower river (below RM 200) and are attributed to turbid inflows from the Illinois and Missouri River (Figure 36). The Minnesota River (RM 844) is the major source of TSS in the upper portion of the river and contributes to elevated concentrations from its confluence with the UMR to the St. Croix River (RM 811.5) where levels decrease due to dilution (Figures 37 and 38). Lowest TSS concentrations in the UMR are normally found at the mouth of Lake Pepin (RM 764.5), a 25-mile long natural riverine lake, which acts as an effective sediment trap. Unfortunately, this lake is rapidly losing depth due to increased

Figure 33 - Total Phosphorus Concentrations in the Upper Mississippi River

Summer Data Collected over Four Time Periods

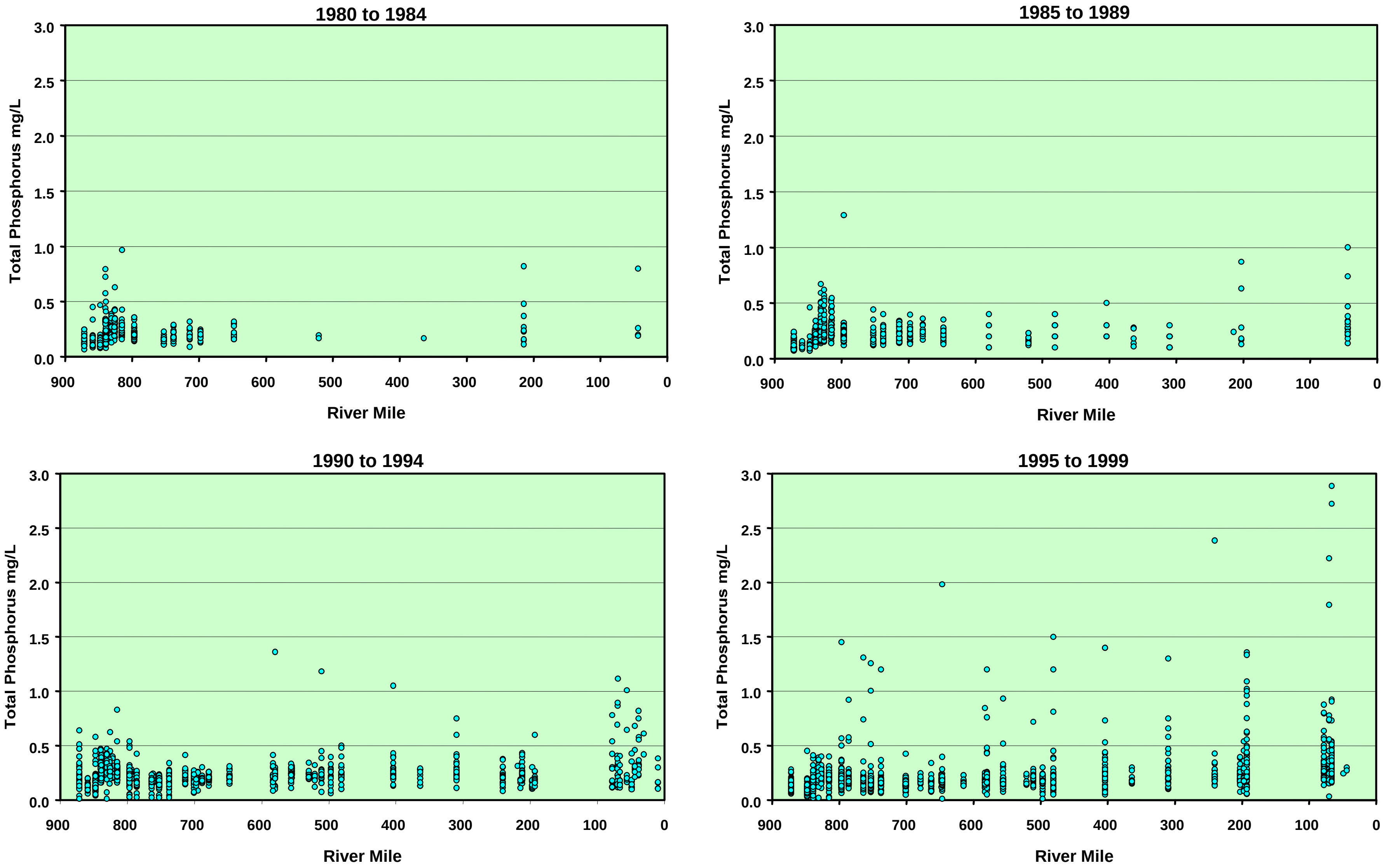


Figure 34: Boxplots of Total Phosphorous Data by HUC over four time periods

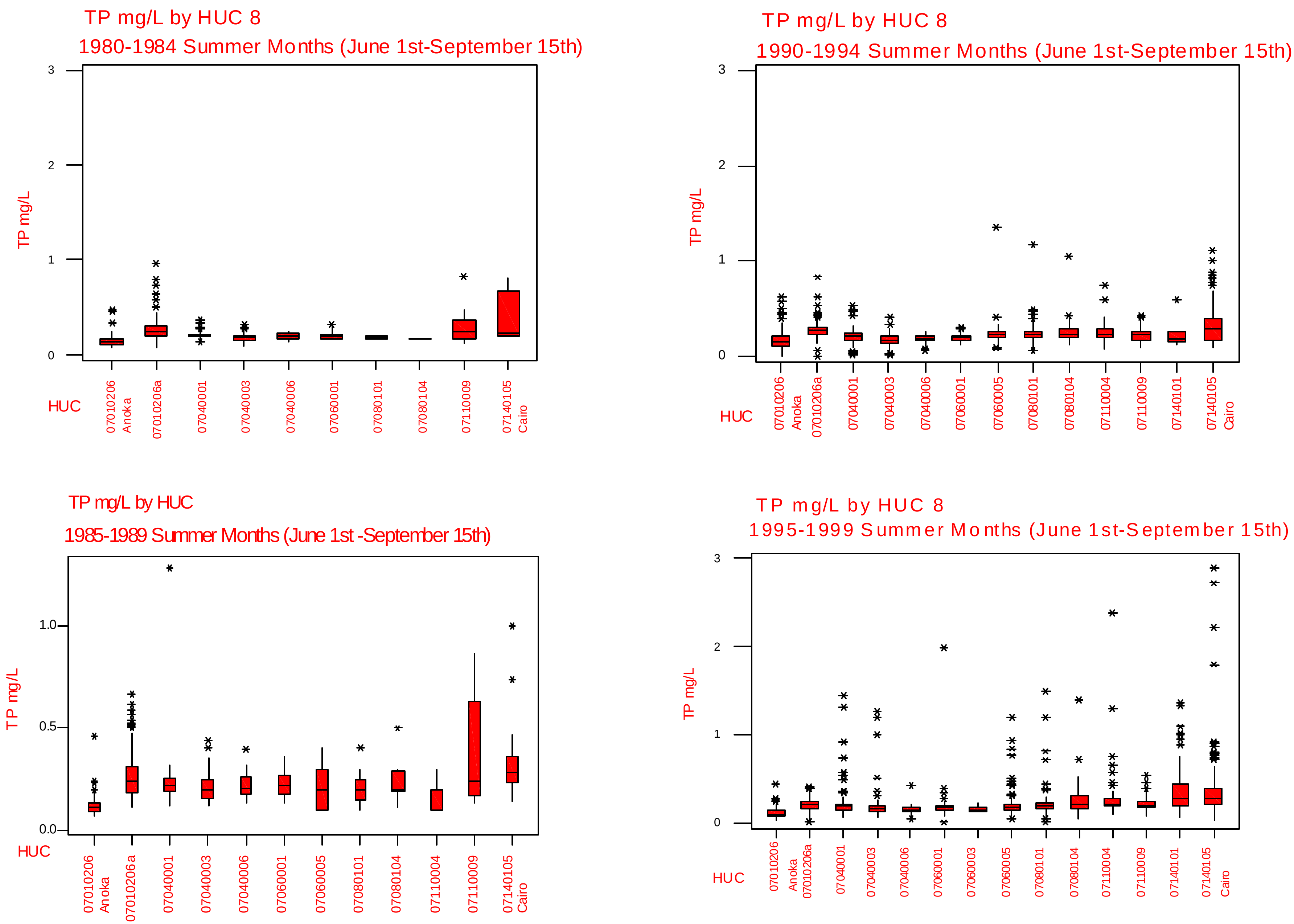


Figure 35: Boxplot of Total Phosphorous Data by HUC over 20 years

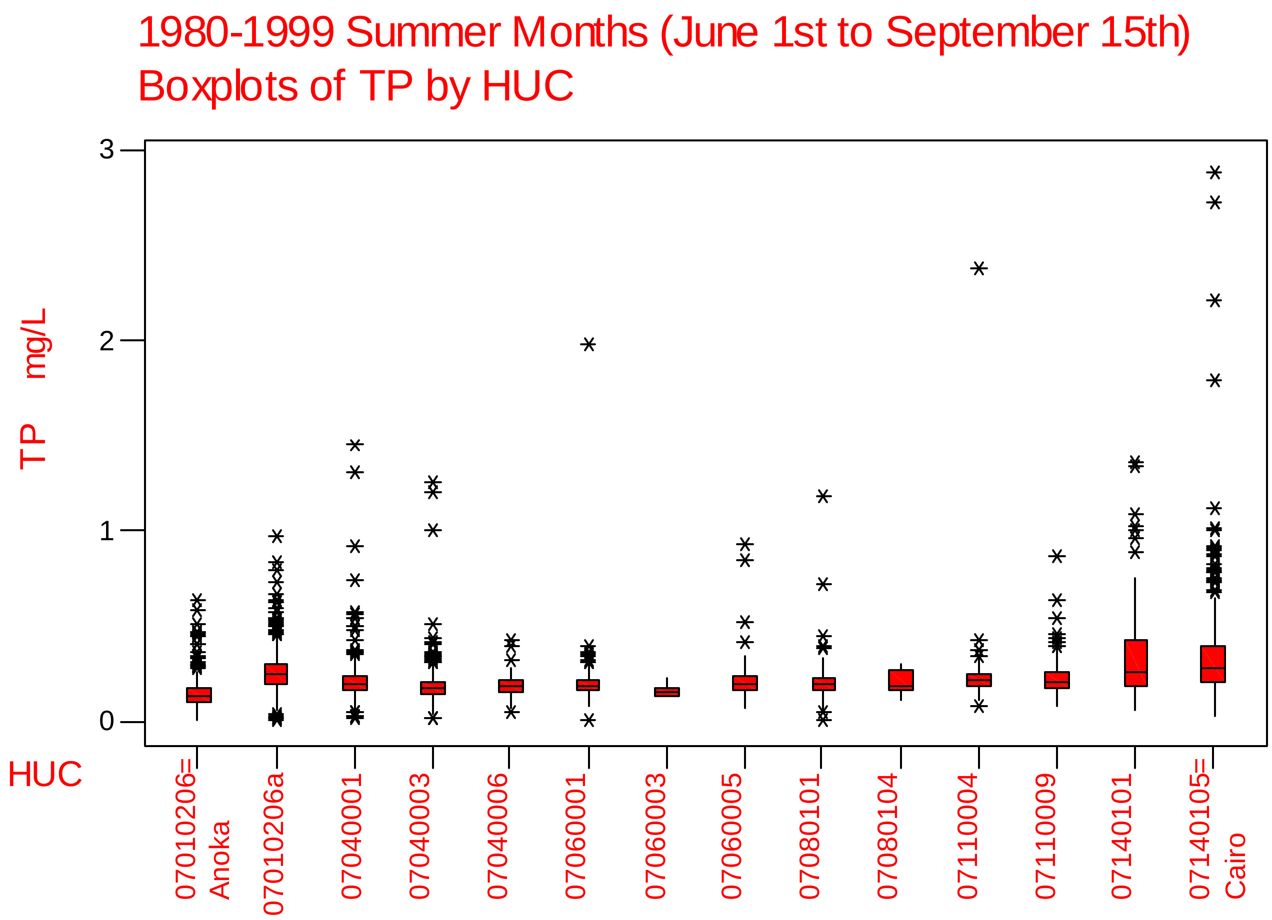


Figure 36 - Total Suspended Solid Concentrations in the Upper Mississippi River

Summer Data Collected over Four Time Periods

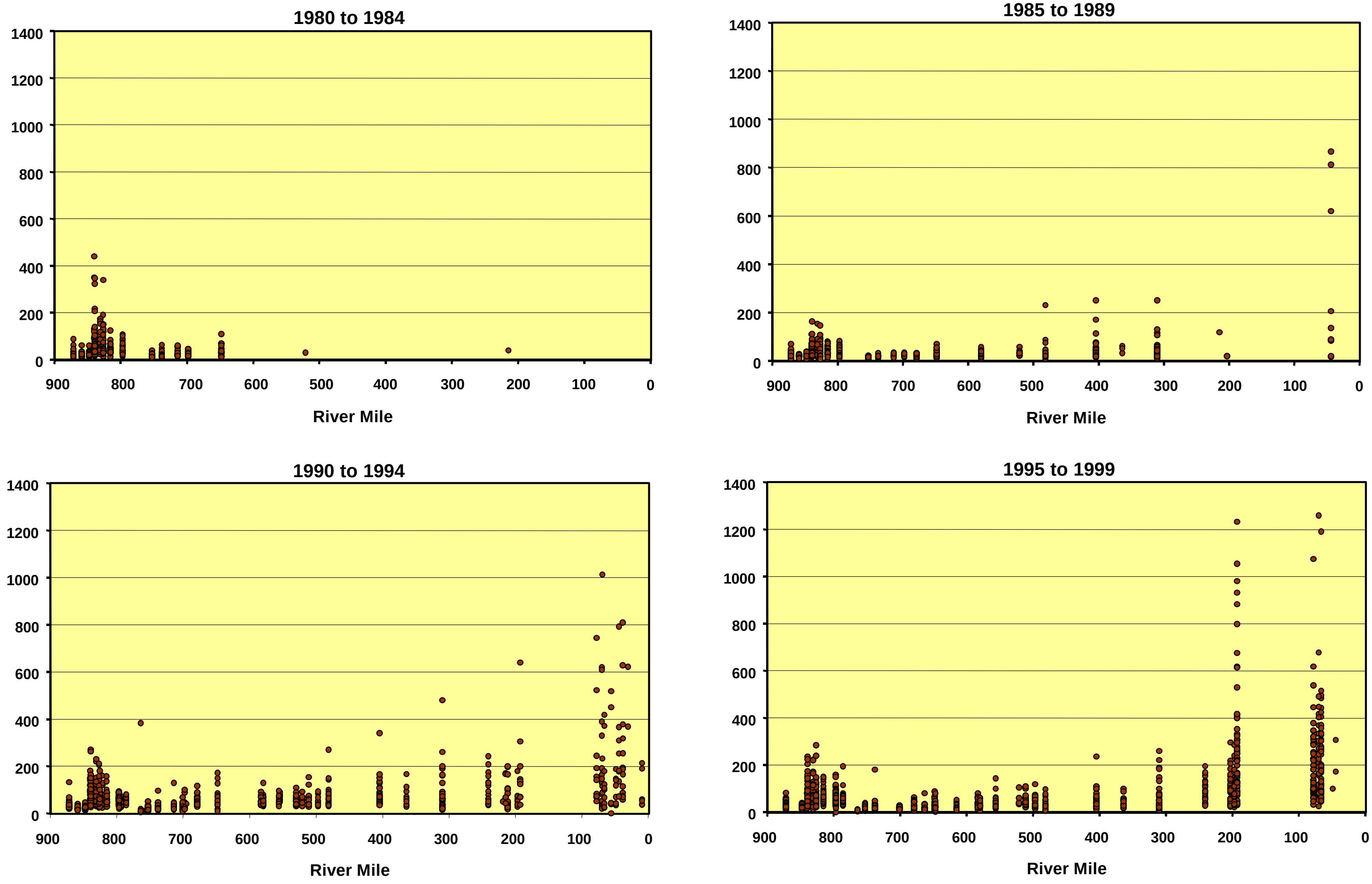


Figure 37 : Boxplots of Total Suspended Solids Data by HUC over four time periods

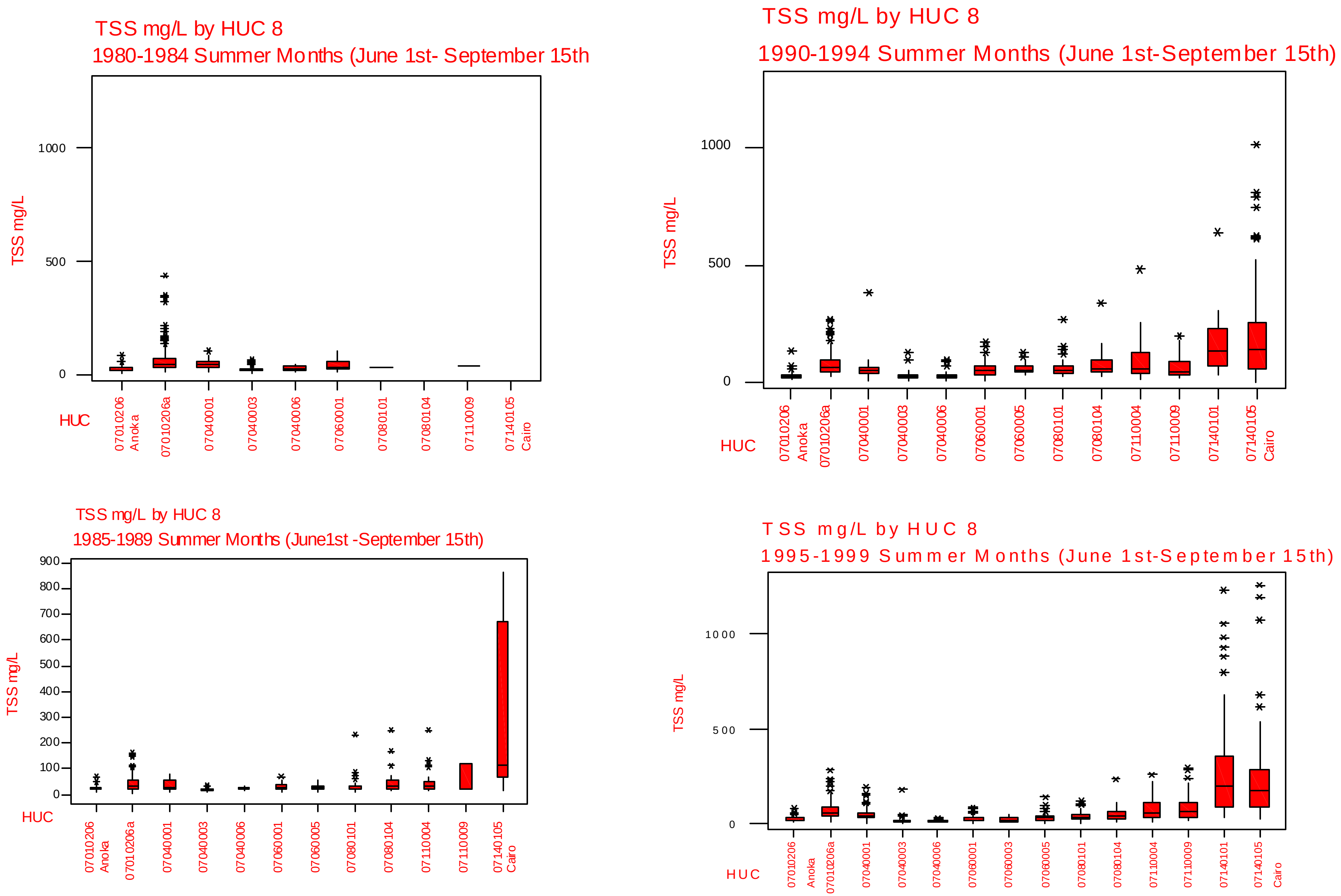


Figure 38: Boxplot of Total Suspended Solids Data by HUC over 20 years